NASA-CR-200678

NAG 51058

Progress Report on

Studies of

Trade-Wind Cloudiness and Climate

Principal Investigator:

David A. Randall

Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523

Covering the period 1 August 1994 - 31 July 1995

This project consists of a modeling study of the tradewind boundary layer and its effects on the general circulation of the atmosphere, on the deep convection downstream, and on the radiative energy budget of the subtropical and tropical oceans. Emphasis will be placed on tradewind processes which produce clouds in the radiative sense, and on improving the tradewind boundary layer simulation produced by general circulation models.

Our progress to date on the various tasks is as follows:

1. Construct a simple one-dimensional model of the tradewind boundary layer.

We have constructed a simple tradewind boundary-layer model based on the second-order bulk model of Randall et al. (1992). The model has been endowed with both a radiation parameterization and a bulk microphysics parameterization. A new surface flux parameterization has been developed and tested (Zhang et al. 1996).

In addition, we have performed some idealized simulations of closed mesoscale cellular convection, and have also formulated a simple weakly nonlinear analytical model of the same phenomenon. A journal article on this work has been accepted for publication (Shao and Randall 1996).

We are now in the process of extending the model by implementing it as a second-order closure model with variable vertical resolution. The second and third moments involving the vertical velocity and the thermodynamic variables are parameterized using the second-order bulk model of Randall et al .(1992). The surface fluxes are parameterized in terms of the turbulence kinetic energy, following Zhang et al. (1996).

2. Test the model by using ASTEX data, and also by using a cloud ensemble model.

We have conducted several numerical experiments, set up to simulate the ASTEX data, using the cloud ensemble model developed by S. Krueger and A. Arakawa at UCLA (Krueger, 1985; 1988). In addition, the second-order bulk model is being run with the same ASTEX conditions, in an offline mode. The results are quite reasonable (Bechtold et al. 1996; Chen 1996) and are being extensively compared with the observations.

3. Incorporate the model into the CSU GCM.

The new surface flux parameterization has been tested in the GCM. We are preparing to test the second-order closure model in the GCM as well.

4. Using the CSU GCM, simulate the observed distribution of tradewind cumulus clouds over the tropical oceans, and the associated vertical profiles of temperature and moisture.

We have conducted an AMIP simulation with the modified version of the GCM. The distributions of boundary-layer clouds and surface wind stress are much more realistic now than in previous versions of the model. We are currently preparing to test the improved atmospheric model as coupled with a dyanamical model of the tropical Pacific Ocean. Our goals are to investigate the coupled model's ability to simulate both the seasonally varying basic state and the occurance of El Niños.

Publications Resulting From This Project

a) Journal articles

1. Moeng, C.-H., D. H. Lenschow, and D. A. Randall, 1995: Numerical Investigations off the Roles of Radiative and Evaporative Feedbacks in Stratocumulus Entrainment and Breakup. *Journal of the Atmospheric Sciences*, **52**, 2869-2883.

2. Shao, Q., and D. A. Randall, 1996: Closed Mesoscale Cellular Convection Driven by Cloud-Top Cooling. *Journal of the Atmospheric Sciences* (in press).

3. Zhang, C., D. A. Randall, and C.-H. Moeng, M. Branson, K. A. Moyer, and Q. Wang, 1996: A surface flux parameterization based on the vertically averaged turbulence kinetic energy. Conditionally accepted for publication in the *Monthly Weather Review*.

4. Bechtold, P., S. K. Krueger, W. S. Lewellen, E. van Meijgaard, C.-H. Moeng, D. A. Randall, A. van Ulden, and S. Wang, 1996: First GCSS boundary layer modeling workshop on a stratocumulus-topped PBL: Intercomparison among different 1D codes and LES. Submitted to the *Bulletin of the American Meteorological Society*.

b) *Other publications*

1. Shao, Q., and D. A. Randall, 1994: Closed mesoscale cellular convection driven by cloud-top cooling. Paper presented at the *Spring AGU Meeting*, Baltimore, Maryland.

2. Chen, A., 1996: *A bulk boundary-layer cloud model with a dizzle parameterization.* M. S. Thesis, Colorado State University.

REFERENCES

Krueger, S. K., 1985: Numerical simulation of tropical cumulus clouds and their interaction with the subcloud layer. Ph.D. Dissertation, Dept. of Atmospheric Sciences, UCLA, 205 p.

Krueger, S. K., 1988: Numerical simulation of tropical cumulus clouds and their interaction with the subcloud layer. *J. Atmos. Sci.*, **45**, 2221-2250.

Randall, D. A., Q. Shao, and C.-H. Moeng 1992: A Second-Order Bulk Boundary-Layer Model. *Journal of the Atmospheric Sciences*, **49**, 1903-1923.

Shao, Q., and D. A. Randall, 1996: Closed Mesoscale Cellular Convection Driven by Cloud-Top Cooling. *Journal of the Atmospheric Sciences* (in press).

Zhang, C., D. A. Randall, and C.-H. Moeng, M. Branson, K. A. Moyer, and Q. Wang, 1996: A surface flux parameterization based on the vertically averaged turbulence kinetic energy. Conditionally accepted for publication in the *Monthly Weather Review*.